HEAD-UP DISPLAY SYSTEM UTILIZING FLUORESCENT MATERIAL

BACKGROUND OF THE INVENTION

Cross-Reference to Related Application

[0001] This application claims the benefits of United States Application Serial No. 60/262,146 filed January 16, 2001, which is herein incorporated by reference in its entirety.

1. Field of the Invention

[0002] This invention relates generally to image and/or information display systems and, in one embodiment, to an improved display system utilizing fluorescent material(s) which is particularly useful in a vehicle head-up display system.

2. Technical Considerations

[0003] A head-up display (HUD) system displays information, such as an image, to a viewer while the viewer simultaneously views the real world around and through the displayed image. Head-up display systems are often incorporated into aircraft cockpits for pilots to monitor flight information. More recently, head-up display systems have been used in land vehicles, such as cars, trucks, and the like. The displayed image is generally positioned so that the vehicle operator can see the image from a normal operating position and does not have to glance downwardly to the vehicle dashboard and away from the viewing area in front of the vehicle.

[0004] A conventional head-up display system typically includes a matrix of light emitting diodes (LED) which can be selectively illuminated to form an image. A collimator aligns the light rays from the LEDs and directs them toward a combiner that reflects the image toward the viewer. For automotive use, laminated windshields have been used as the combiner. Examples of automotive head-up display systems are disclosed, for example, in U.S. Patent Nos. 2,264,044 and 5,013,134, and International Publication No. WO 91/06031, all of which are herein incorporated by reference.

[0005] While these known vehicle head-up display systems are generally adequate for automotive use, improvements could be made. For example, in these conventional automotive head-up display systems the resolution of the reflected image is limited by the size of the LED matrix, i.e., the number of rows and columns of LEDs used to generate the image. Additionally, in strong sunlight, the reflected image from the LED matrix can be difficult to read. Further, reflection of the image from each of the interfaces of the windshield, especially the air-glass interfaces, creates multiple images that can reduce overall image clarity. Moreover, these conventional head-up display systems are designed so that the reflected image can be viewed only by the vehicle operator, not vehicle passengers. Additionally, if the curvature of the windshield deviates from designed specifications, the reflected image can appear distorted and can be difficult to discern.

[0006] Therefore, it would be advantageous to provide an image and/or information display system, particularly an automotive head-up display system, which reduces or eliminates at least some of the drawbacks discussed above.

SUMMARY OF THE INVENTION

[0007] The present invention provides a method of displaying images and a display system, e.g., a head-up display system, which are particularly useful in vehicles, such as aircraft, automobiles, trucks, etc. The display system includes one or more light emitting materials, such as one or more fluorescent and/or phosphorescent materials, carried on a support and a projection assembly having an electromagnetic radiation source. The projection assembly is configured to direct electromagnetic radiation of one or more selected wavelength(s) toward the light emitting material to cause at least a portion of the light emitting material to emit light, e.g., fluoresce or phosphoresce, to form an image.

The electromagnetic radiation source can be selectively directed and/or controlled to generate a desired image. In one specific embodiment of the invention, the support is a laminated windshield with fluorescent material located between the plies of the laminate. The windshield can have a first portion which is substantially transparent to the selected wavelength(s) and a second portion which is substantially non-transparent to the selected wavelength(s). In another aspect, the support is a non-laminated entertainment display.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Fig. 1 is a schematic view (not to scale) of a head-up display system for a vehicle which incorporates features of the present invention;

[0009] Fig. 2 is a side view (not to scale) of a support with fluorescent material incorporating features of the invention;

[0010] Fig. 3 is a front view of a fluorescent image formed in accordance with the teachings of the present invention;

[0011] Fig. 4 is a schematic view (not to scale) of an alternative embodiment of a projecting assembly for use with a head-up display system of the invention; and

[0012] Fig. 5 is a graph of percent transmittance versus wavelength comparing a clear glass ply to a laminated article described in Example 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0013] As used herein, spatial or directional terms, such as "inner", "outer", "left", "right", "up", "down", "horizontal", "vertical", and the like, relate to the invention as it is shown in the drawing figures. However, it is to be understood that the invention can assume various alternative orientations and, accordingly, such terms are not to be considered as limiting. Further, all numbers expressing dimensions, physical characteristics, and so forth, used in

the specification and claims are to be understood as being modified in all instances by the term "about". Accordingly, unless indicated to the contrary, the numerical values set forth in the following specification and claims can vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should at least be construed in light of the number of reported significant digits and by applying ordinary rounding techniques. Moreover, all ranges disclosed herein are to be understood to encompass any and all subranges subsumed therein. For example, a stated range of "1 to 10" should be considered to include any and all subranges between (and inclusive of) the minimum value of 1 and the maximum value of 10; that is, all subranges beginning with a minimum value of 1 or more and ending with a maximum value of 10 or less, e.g., 5.5 to 10. Also, as used herein, the terms "deposited over", "applied over", or "provided over" mean deposited, applied, or provided on but not necessarily in surface contact with. For example, a material "deposited over" a substrate does not preclude the presence of one or more other materials of the same or different composition located between the deposited material and the substrate.

[0014] In the following discussion, a display system incorporating features of the invention will be discussed generally with reference to use in a head-up display system for a vehicle, such as an automobile. However, it is to be understood that the specifically disclosed exemplary apparatus and method are presented simply to explain the general concepts of the invention and that the invention is not limited to these specific exemplary embodiments. As would be appreciated by those skilled in the art, the invention can be practiced in many fields, such as but not limited to, laminated or non-laminated residential and/or commercial

windows, insulating glass units, commercial signs, entertainment displays, advertising displays, monitors for televisions or computers, and/or transparencies for land, air, space, above water and under water vehicles, e.g., automotive windshields, sidelights, back lights, sunroofs, and moon roofs, just to name a few.

[0015] An exemplary display system incorporating features of the invention is illustrated in Fig. 1 as a vehicle head-up display system 10 and includes one or more light emitting materials, e.g., fluorescent or phosphorescent materials, carried on a support 12. In the following discussion, the light emitting material is a fluorescent material 11. The display system 10 also includes a projection assembly 14. The components of the exemplary head-up display system 10 shown in Fig. 1 will first be described and then operation of the head-up display system 10 to practice an exemplary method of the invention will be described.

[0016] The support 12 can be of any desired type, such as but not limited to, a single ply or a laminated article. In the exemplary embodiment shown in Fig. 1, but not to be considered as limiting to the invention, the support 12 is shown as a laminated article having a first ply 18 with a major surface facing the vehicle interior, i.e., an inner major surface 20, and an opposed or outer major surface 22. The support 12 also includes a second ply 24 having an inner major surface 26 and an outer major surface 28. The first and second plies 18, 24 can be bonded together in any suitable manner, such as by an interlayer 32. A conventional edge sealant 34 can be applied to the perimeter of the laminated article during and/or after lamination in any desired manner. A decorative band 36, e.g., an opaque, translucent or colored shade band, such as a ceramic band, can be provided on a surface of at least one of the plies 18, 24, for example around the perimeter of the inner major surface 20 of the first ply 18.

[0017] In the broad practice of the invention, the support 12 (e.g., the first and second plies 18, 24) can be of any desired material having any desired optical characteristics. For example, the plies 18, 24 can be transparent to visible light. By "transparent" is meant having a transmittance of greater than 0% to 100%. By "visible light" is meant electromagnetic energy in the range of 390 nm to 800 nm. Alternatively, the support 12 can be translucent or opaque. By "translucent" is meant allowing electromagnetic energy (e.g., visible light) to pass through but diffusing it such that objects on the other side are not clearly visible. By "opaque" is meant having a visible light transmittance of 0%. The plies 18 and 24 can be of the same or different materials.

[0018] For automotive use, the first and second plies 18, 24 are each preferably made of a transparent material, such as plastic (e.g., polymethylmethacrylate, polycarbonate, polyurethane, polyethyleneterephthalate (PET), or copolymers of any monomers for preparing these, or mixtures thereof), ceramic or, more preferably, glass. The glass can be of any type, such as conventional float glass or flat glass, and can be of any composition having any optical properties, e.g., any value of visible transmission, ultraviolet transmission, infrared transmission, and/or total solar energy transmission. By "float glass" is meant glass formed by a conventional float process in which molten glass is deposited onto a molten metal bath and controllably cooled to form a float glass ribbon. The ribbon is then cut and/or shaped and/or heat treated as desired. Examples of float glass processes are disclosed in U.S. Patent Nos. 4,466,562 and 4,671,155. The glass can be, for example, conventional soda-lime-silicate glass, borosilicate glass, or leaded glass. The glass can be clear glass. By "clear glass" is meant non-tinted or non-colored glass. Alternatively, the glass can be tinted or otherwise colored glass. The glass can be untempered, heat treated, or heat strengthened glass. As used herein, the term "heat

strengthened" means annealed, tempered, or at least partially tempered. The first and second plies 18, 24 can each be clear float glass or can be tinted or colored glass or one ply can be clear glass and the other colored glass. Although not limiting to the invention, examples of glass suitable for the first ply 18 and/or second ply 24 are described in U.S. Patent Nos. 4,746,347; 4,792,536; 5,240,886; 5,385,872; and 5,393,593, which are herein incorporated by reference. The first and second plies 18, 24 can be of any desired dimensions, e.g., length, width, shape, or thickness. For use in automotive transparencies, the first and second plies 18, 24 can each be 1 mm to 10 mm thick, e.g., less than 10 mm thick, e.g., 1 mm to 5 mm thick, e.g., 1.5 mm to 2.5 mm, e.g., 1.8 mm to 2.3 mm.

[0019] The interlayer 32 can be of any desired material and can include one or more layers or plies. As will be described in more detail below, the interlayer material can be a material selected to block, absorb, or at least attenuate the transmission of electromagnetic energy of one or more selected wavelengths. The interlayer 32 can be a plastic material such as, for example, polyvinyl butyral, plasticized polyvinyl chloride, or multi-layered thermoplastic materials including polyethylene terephthalate, etc. Suitable interlayer materials are disclosed, for example but not to be considered as limiting, in U.S. Patent Nos. 4,287,107 and 3,762,988, which are herein incorporated by reference. In the exemplary embodiment shown in Fig. 1, the interlayer 32 is a single polyvinyl butyral ply having a thickness of 0.5 mm to 1 mm, e.g., 0.76 mm. The interlayer 32 secures the first and second plies 18, 24 together, provides energy absorption, reduces noise, and increases the strength of the laminated structure. The interlayer 32 can also be a sound absorbing or attenuating material as described, for example, in U.S. Patent No. 5,796,055, which is herein incorporated by reference. The interlayer 32 can have a solar control coating provided

thereon or incorporated therein or can include a colored material to reduce solar energy transmission.

[0020] In the practice of the invention, the light emitting material (e.g., fluorescent material 11) is carried on all or at least a portion of the support 12, e.g., on all or at least a portion of a major surface of the support 12. Alternatively, the fluorescent material 11 can be on a surface of or incorporated into the interlayer 32. The fluorescent material 11 can be applied in any conventional manner, such as but not limited to dissolving the fluorescent material 11 in a solvent and applying the resultant solution onto the substrate by spraying, dipping, or rolling. Alternatively, the dry fluorescent material 11 can be press-applied onto one or more major surfaces of the substrate 12. In the exemplary laminated support 12 shown in Fig. 1, the fluorescent material 11 can be located between the first ply 18 and the second ply 24, e.g., between the first ply 18 and the interlayer 32. For example, the fluorescent material 11 can form a continuous coating layer on all or at least a portion of the support 12. Alternatively, the fluorescent material 11 can be present in discreet sections or areas or can be present in non-film form, such as inorganic crystalline powders or organic fluorescent materials deposited on or carried on the support 12.

[0021] As used herein, the term "light emitting material" means a material that emits electromagnetic radiation, e.g., in the visible region of 390 nm to 800 nm, upon exposure to external radiation. Exemplary light emitting materials suitable for the practice of the invention include fluorescent and phosphorescent materials. In one embodiment, the light emitting material (e.g., fluorescent material 11) absorbs electromagnetic energy in one region of the electromagnetic spectrum (e.g., at one or more first wavelength(s)) and emits electromagnetic energy at another region of the electromagnetic spectrum (e.g., one or more second wavelength(s)), which can be different than the first

wavelength(s). Typically, although not required, the second wavelength(s) are longer than the first wavelength(s). In one embodiment, the fluorescent material 11 absorbs electromagnetic energy in at least a portion of the visible (390 nm to 800 nm) and/or ultraviolet (300 nm to 390 nm) ranges of the electromagnetic spectrum, e.g., one or more wavelengths greater than 300 nm, e.g., one or more wavelengths less than 800 nm, e.g., one or more wavelengths in the range of 300 nm to 800 nm. In a particular embodiment of the invention, the fluorescent material 11 absorbs energy (e.g., one or more wavelengths) within a region of the electromagnetic spectrum between 300 nm to 500 nm, such as in a range of 325 nm to 425 nm, e.g., 350 nm to 410 nm, e.g., 397 nm. The portion of the electromagnetic spectrum or wavelength(s) of the electromagnetic spectrum absorbed by the light emitting material (e.g., fluorescent material 11) is generally referred to herein as the "absorption band" of the fluorescent material 11. The fluorescent material 11 preferably fluoresces at one or more wavelengths close to or in the visible range, such as between 380 nm to 800 nm of the electromagnetic spectrum.

[0022] The light emitting material, e.g., fluorescent material 11, can be any type of light emitting material, such but not limited to one or more organic, organo-metallic, or inorganic light emitting (e.g., fluorescent and/or phosphorescent) materials, and can be present in any desired amount. An example of one fluorescent material 11 suitable for the practice of the invention is Uvitex® OB fluorescent material commercially available from Ciba Specialty Chemicals Corporation. Other suitable light emitting organic materials include stibene, styrene, and ethylene species supplemented with one or more heterocyclic substituents such as benzoxazolyl, v-triazolyl, oxadiazolyl, or s-triazinylamino groups. Other suitable inorganic light emitting materials include oxides, sulfides, or oxide-sulfides of metals that are

"doped" with (i.e., include small amounts of) ions of another metal, e.g. Y_2O_3:Eu, YVO_4:Tm, ZnS:Mn, Y_2O_2S:Pr, and Gd_2O_2S:Tb. However, as will be understood by one of ordinary skill in the art, the particular light emitting, e.g., fluorescent, material utilized can be selected based on the electromagnetic radiation source used in the projection assembly 14 described below and/or by the desired wavelength of the light emitted from the fluorescent material 11, such as to produce an image of one or more desired colors. The amount of fluorescent material 11 can be any amount to provide a desired level of fluorescent brightness, i.e., the brightness of the fluorescent image. As a general rule, as more fluorescent material 11 is placed on the support 12, the brighter will be the resultant fluorescent image until the point is reached where all of the incoming electromagnetic energy is absorbed by the fluorescent material. In addition to or in lieu of the fluorescent material 11, the invention could also be practiced with phosphorescent material.

[0023] With continued reference to Fig. 1, a functional coating 42 can also be carried on the support 12. The functional coating 42 can be a coating which affects the solar properties, e.g., emissivity, shading coefficient, transmission, absorption, reflection, etc., or conductive properties, e.g., thermal or electrical conduction, of the support 12.

[0024] The functional coating 42 can be of any desired type. As used herein, the term "coating" includes one or more coating layers and/or coating films. The functional coating 42 can have one or more functional coating layers or films of the same or different composition or functionality. As used herein, the terms "layer" or "film" refer to a coating region of a desired or selected coating composition.

[0025] Although not limiting to the invention, the functional coating 42 can be a coating which affects the solar control properties, e.g., emissivity, shading coefficient,

transmission, absorption, reflection, etc., or conductive properties, e.g., thermal or electrical conduction, of the functionally coated support 12. For example, but not to be considered as limiting, the functional coating 42 can be an electroconductive coating, a heatable coating, an antenna coating, or a solar control coating, such as a low emissivity coating. As used herein, the term "solar control coating" refers to a coating which affects the solar properties of the coated article, such as but not limited to, shading coefficient and/or emissivity and/or the amount of solar radiation reflected and/or absorbed by and/or transmitted through the coated article, e.g., infrared or ultraviolet absorption or reflection. The solar control coating can block, absorb, or filter selected portions of the solar spectrum, such as but not limited to, the visible spectrum. Non-limiting examples of solar control and antenna coatings are disclosed in U.S. Patent Nos. 4,898,789; 5,821,001; 4,716,086; 4,610,771; 4,902,580; 4,716,086; 4,806,220; 4,898,790; 4,834,857; 4,948,677; 5,059,295; and 5,028,579, which patents are herein incorporated by reference. Non-limiting examples of electroconductive coatings are disclosed in U.S. Patent Nos. 5,653,903 and 5,028,759, which are herein incorporated by reference.

[0026] In one exemplary embodiment, the functional coating 42 can be a low emissivity coating. As will be appreciated by one skilled in the art, a "low emissivity" coating can have different emissivity values depending upon how the coating is deposited. For example, low emissivity sputter applied coatings typically have an emissivity in the range of 0.01 to 0.06, depending on the number of reflective metal layers present in the coating. Low emissivity pyrolytically applied coatings typically have an emissivity in the range of less than 0.03. Therefore, as generally used herein, the term "low emissivity" means an emissivity less than 0.1, such as less than 0.05. Examples of low emissivity coatings are found, for

example, in U.S. Patent Nos. 4,952,423 and 4,504,109. The functional coating 42 can be a single layer or multiple layer coating and can comprise one or more metals, non-metals, semi-metals, semiconductors and/or alloys, compounds, composites, combinations, or blends thereof. For example, the functional coating 42 can be a single layer metal oxide coating, a multiple layer metal oxide coating, a non-metal oxide coating, or a multiple layer coating.

[0027] Non-limiting examples of functional coatings 42 which can be used with the invention are commercially available from PPG Industries, Inc. of Pittsburgh, Pennsylvania under the SUNGATE® and SOLARBAN® families of coatings. Such functional coatings typically include one or more anti-reflective coating films comprising dielectric or anti-reflective materials, such as metal oxides or oxides of metal alloys, which are transparent or substantially transparent to visible light. The functional coating 42 can also include infrared reflective films having a reflective metal, e.g., a noble metal such as gold, copper, or silver, or combinations or alloys thereof, and can further include a primer film or barrier film, such as titanium, as is known in the art, located over and/or under the metal reflective layers.

[0028] The functional coating 42 can be deposited over all or at least a portion of a major surface of at least one of the plies 18, 24. In the exemplary embodiment shown in Fig. 1, the functional coating 42 is deposited over the inner major surface 26 of the second ply 24. However, it is to be understood that the functional coating 42 is not limited to this location. The functional coating 42 can be, for example, located on any of the major surfaces of the first ply 18 or second ply 24 or on or incorporated into the interlayer 32. The functional coating 42 can be deposited in any conventional manner, such as but not limited to, magnetron sputter vapor deposition (MSVD), chemical vapor deposition (CVD), spray

pyrolysis (i.e., pyrolytic deposition), atmospheric pressure CVD (APCVD), low-pressure CVD (LPCVD), plasma-enhanced CVD (PECVD), plasma assisted CVD (PACVD), thermal or electron-beam evaporation, cathodic arc deposition, plasma spray deposition, and wet chemical deposition (e.g., sol-gel). The functional coating 42 can be of any desired type or thickness, such as a solar control coating having a thickness of 700 Å to 1000 Å. The functional coating 42 can have any number or type of infrared reflective layers, such as one or more silver layers, e.g., 2 or more silver layers.

[0029] Although in the exemplary embodiment described above the support 12 is a laminated article having the fluorescent material 11 located between the plies, it should be understood that the invention is not limited to this embodiment, e.g., the fluorescent material 11 can be located on an outer major surface of the laminated article or, as shown in Fig. 2, the support 12 could be a "monolithic" article 45 with the fluorescent material 11 located on at least a portion of one or more surfaces of the monolithic article 45. By "monolithic" is meant an article having a single structural substrate or primary ply, e.g., a glass ply. By "primary ply" is meant a primary support or structural member. For example, as shown in Fig. 2, the support 12 could be formed by a single ply 46 having a first major surface 48 and a second major surface 50 with the fluorescent material 11 deposited over or carried on all or at least a portion of at least one of the major surfaces 48, 50. The single ply 46 can be of any material having any desired optical characteristics, such as those described above. A protective coating (not shown in Fig. 2), e.g., a metal or metal oxide coating, can be deposited over the fluorescent material 11 to protect the fluorescent material 11 from chemical or mechanical wear. Alternatively or additionally, a functional coating 42 (not shown in Fig. 2), such as described above, could also be deposited over at least a portion of the one or more of the

major surfaces 48, 50 (either over or under the fluorescent material) to provide the support 12 with solar control features. An electromagnetic radiation absorbing material 52, such as the interlayer material described above or a similar material, could also be deposited over all or at least a portion of one or more of the major surfaces 48, 50 of the ply 46 to reduce or eliminate electromagnetic radiation of selected wavelengths passing through the support 12. It is also to be understood that in this embodiment (without a radiation absorbing material) the radiation from the radiation source 60 can be directed at the fluorescent material from either side of the support 12.

[0030] As described above, the support 12 can be an automotive transparency. As used herein, the term "automotive transparency" refers to an automotive windshield, sidelight, back light, moon roof, sunroof, and the like. The automotive transparency can have a visible light transmission of any desired amount, e.g., greater than 0% to 100%, e.g., greater than 70%. For non-privacy areas, the visible light transmission can be greater than or equal to 70%. For privacy areas, the visible light transmission can be less than 70%.

[0031] As discussed below, the invention is not limited to use with vehicle or automotive transparencies. For example, the monolithic article 45 shown in Fig. 2 could be a residential or commercial window, an advertising display, or a commercial sign configured to display fluorescent images in a similar manner as described below. Further, the support 12 could be a pane of a conventional insulating glass unit. The support 12 upon which the fluorescent material 11 is carried can be a transparent article, a translucent article, or an opaque article.

[0032] With continuing reference to Fig. 1, the display system of the invention, e.g., the head-up display system 10, can also include a projection assembly 14. Although not limiting to the invention, one exemplary projection assembly

14 is schematically shown in Fig. 1 and includes an energy source or radiation source 60, e.g., an electromagnetic radiation source capable of emitting radiation, e.g., electromagnetic radiation, of one or more selected wavelengths within at least a portion of the absorption band of the fluorescent material 11. As used herein, the term "selected wavelength" means a single wavelength or a range of wavelengths. However, at least a portion of the selected wavelength should be within the absorption band of the fluorescent material 11. In one exemplary embodiment, the radiation source 60 is a laser or laser diode capable of emitting electromagnetic radiation of one or more selected wavelengths, for example, in the range of 300 nm to 500 nm, such as in the range of 325 nm to 425 nm, e.g., in the range of 350 nm to 410 nm, e.g., in the range of 390 nm to 400 nm, e.g., 397 nm. However, it will be understood by one of ordinary skill in the art that the selected wavelength of the radiation source 60 can be selected based on the specific fluorescent material 11 utilized so that all or at least a portion of the selected wavelength range is at least partly within the absorption band of the fluorescent material 11 being used. Suitable radiation sources include Model PPM04 (LD1349) and Model PPMT25/5255 (LD1380) laser diodes commercially available from Power Technologies, Inc. The radiation sources can be of any desired power output, such as 5 mW to 100 mW, e.g., 5 mW to 30 mW. Other suitable radiation sources are commercially available from Edmund Industrial Optics and Coherent Auburn Division. As a general rule, as the output power of the radiation source increases, the brightness of the fluorescent image produced also increases.

[0033] The projection assembly 14 can include a directing system 62 (e.g., a scanner) to the direct or scan radiation emitted from the radiation source 60 toward the fluorescent material 11. The directing system 62 can include one or more directors 64, such as a mirror or combination of two or more

mirrors, each movably mounted on a movement device 66, such as a conventional mechanical or electrical positioning device. For example, the director 64 can include two mirrors, one for vertical movement and one for horizontal movement of radiation from the radiation source 60. As will be described in more detail below, the movement device 66 is configured to move the director 64 to selectively direct the radiation emitted from the radiation source 60 toward one or more selected areas of the fluorescent material 11. A suitable director 64 is a Model 6800HP scanner commercially available from Cambridge Technology, Inc.

[0034] A blocking device 67 can be located between the radiation source 60 and the directing system 62. For example, the blocking device 67 can be an electro-optical modulator, an electro-mechanical device, or a similar device to selectively block and unblock radiation from the radiation source 60 passing to the directing system 62. For example, the blocking device 67 can include a crystal which switches from being transparent to the selected wavelength(s) to being opaque to the selected wavelength(s) by the application of a voltage.

[0035] The radiation source 60 and/or the directing system 62 and/or blocking device 67 can be connected to a controller 68, such as a conventional computer or electronic control device. The controller 68 can be configured to energize the movement device 66 and to move the director 64 to direct the radiation from the radiation source 60 toward the fluorescent material 11 to form patterns or images, as described below. Additionally, the controller 68 can modulate the power of the radiation source 60 to vary the intensity of the energy beam from the radiation source. In one embodiment, the controller 68 is configured to activate and deactivate the blocking device 67 to block and unblock at least a portion, e.g., all, of the radiation from the radiation source 60 passing to the director 64. If the blocking device 67 is not present, the controller 68 can be configured to energize and deenergize the

radiation source 60 as described below. An example of a suitable controller is a FieldGo portable computer commercially available from Broadax Systems, Inc. Suitable control software includes Microsoft® operating software, e.g., Windows 95®. Suitable imaging software includes "Laser Show Designer for Windows: Professional 2.86" commercially available from Microsoft®.

[0036] The radiation source 60, directing system 62, blocking device 67, and/or controller 68 can be in electronic communication with a conventional power source 70, such as a battery or electrical generator, to supply power to the components of the head-up display system 10. Additionally, the controller 68 can be in electronic communication with one or more vehicle operating systems 72, such as automotive speed sensing systems, alarm systems, global positioning systems, electronic sending or receiving systems, and the like.

[0037] In one embodiment, the material of the interlayer 32 can be selected to absorb at least some, for example all, of the electromagnetic radiation from the radiation source 60 directed toward the support 12 such that little or no electromagnetic radiation from the radiation source 60 passes through the support 12, e.g., to the outside of the vehicle. As will be appreciated by one of ordinary skill in the art, the amount of electromagnetic radiation that passes through the support 12 will depend upon several factors, such as the thickness and/or composition of the plies 18, 24, the thickness and/or composition of the interlayer 32, the amount and/or composition of the fluorescent material 11, and the wavelength(s) of the electromagnetic radiation emitted by the radiation source 60. Thus, the laminated support 12 shown in Fig. 1 and described above can provide a first portion 100 which is transparent or substantially transparent to the electromagnetic radiation emitted by the radiation source 60 and a second portion 102 which is non-transparent or substantially non-transparent to the electromagnetic radiation

emitted by the radiation source 60. By "substantially transparent to the electromagnetic radiation emitted by the radiation source 60" is meant that at least 50% of the electromagnetic radiation emitted by the radiation source 60 (e.g., in the absorption band of the fluorescent material) passes through, for example more than 70%, such as more than 80%, e.g., in the range of 50% to 100%. By "substantially non-transparent to the electromagnetic radiation emitted by the radiation source 60" is meant that less than 50% of the electromagnetic radiation emitted by the radiation source 60 passes through, for example less than 35%, such as less than 20%, e.g., in the range of 50% to 0%. In addition to the interlayer 32, utilizing a colored or tinted, i.e., non-clear, material for the second ply 24, will also absorb some of the electromagnetic radiation emitted by the radiation source 60 directed toward the support 12.

[0038] An exemplary method of practicing the invention will now be described with particular reference to the exemplary head-up display having the laminated support 12 shown in Fig. 1. The controller 68 energizes the radiation source 60 to emit a beam 74 of electromagnetic radiation of one or more selected wavelengths toward the director 64. Assuming the blocking device 67 is in a deenergized or "open" mode, at least a portion, e.g., all, of the emitted radiation passes through the blocking device 67 and onto the director 64. The director 64 redirects this energy beam 74 toward the fluorescent material 11 located on the support 12. The fluorescent material 11 absorbs at least a portion of the electromagnetic radiation and then fluoresces, i.e., emits energy 76, such as energy in the visible region of the electromagnetic spectrum which can be seen by an occupant 78 of the vehicle. The occupant 78 can be the vehicle driver or one or more of the passengers.

[0039] The controller 68 can direct the movement device 66 to point the director 64 to different areas of the fluorescent

material 11 to cause these selected areas of the fluorescent material 11 to fluoresce to form an image visible to the occupant 78. The controller 68 can vary the output, e.g., the power or beam intensity, of the radiation source 60 to cause different areas of the fluorescent material 11 to fluoresce at different levels of brightness. For example, in one exemplary embodiment the director 64 can raster the direction of the radiation beam 74 along a portion or all of the fluorescent material 11. By "raster", is meant to form a scan pattern, e.g., by scanning an area from side to side in lines from top to bottom or bottom to top. As the scan pattern is formed, the controller 68 can selectively energize and deenergize, i.e., open and close, the blocking device 67 to form adjacent fluorescent and non-fluorescent areas on the support 12 to thereby form one or more fluorescent images discernable by the driver. In an alternative embodiment in which no blocking device 67 is present, the controller 68 could energize and deenergize the radiation source 60 to form the fluorescent images.

[0040] An exemplary fluorescent image 80 in the form of the letter "P" formed on a portion 82 of the support 12 is depicted by the shaded area in Fig. 3. In one exemplary method of forming this image 80, the director 64 is moved in first and second directions, e.g., from side to side (as depicted by directions L and R), and is displaced in a substantially perpendicular direction, e.g., up and down (as depicted by directions U and D), to form a scan pattern or a plurality of scan paths 84a to 84g. For purposes of the present explanation only, the individual scan paths 84a to 84g are depicted as being separated by dashed lines in Fig. 3. However, it will be understood that these dashed lines are simply for explanation purposes only and would not be visible during actual operation. The width (W) of the scan paths 84a to 84g can correspond to a width of the beam 74. Adjacent scan paths can be overlapping, i.e. the perpendicular

displacement of the director 64 (in the U or D directions) can be less than the width of the beam 74. On the other hand, the perpendicular displacement of the director 64 can be greater than the width of the beam 74 so that a gap is formed between adjacent scan paths (not shown).

[0041] In one exemplary method of forming the image 80, the director 64 can be traversed from left to right with respect to Fig. 3 along the uppermost scan path 84a with the blocking device 67 energized, i.e., closed. When the director 64 reaches a position equivalent to position 86, i.e., when the director 64 is pointing to position 86, the blocking device 67 can be deenergized while the director 64 continues to traverse to the right (direction R) so that the region of the uppermost scan path 84a from position 86 to position 88 fluoresces. At position 88, the blocking device 67 can be energized (closed) for the remainder of the scan path 84a (i.e., until the director 64 reaches the end of the scan path 84a). The director 64 can then be displaced in direction D to the next scan path 84b and moved in direction L along the scan path 84b to position 88 where the blocking device 67 is again deenergized (opened) from position 88 to position 90. At position 90, the blocking device 67 is energized (closed) until position 92 when the blocking device 67 is again deenergized (open) from position 92 to position 86. At position 86, the blocking device 67 is energized (closed) for the remainder of the scan path 84b, at which time the director 64 is again displaced in direction D to the next scan path 84c. In this manner, the fluorescent image 80 can be formed. While the formation of only a single letter is described above, it will be understood that adjacent letters, words, sentences, numbers, symbols, or images could be formed in a similar manner.

[0042] It is also to be understood that the image forming method of the invention is not limited to the above-described exemplary rastering embodiment. For example, while in the

above-described method the director 64 is alternately moved laterally from left to right and right to left across the fluorescent material 11 while energizing and deenergizing the blocking device 67 to form the image 80, the director 64 could alternatively be laterally moved in only one direction while forming the image 80, e.g., always to the right or always to the left while forming the scan pattern in similar manner to the movement of an electron beam in a conventional cathode ray tube image system. For example, the director 64 could start on the upper left scan path 84a and scan to the right while energizing and deenergizing the blocking device 67. At the end of the scan path 84a, the blocking device 67 can be energized (closed), the director moved to the left and down to the left side of the next scan path 84b, and then the director 64 moved to the right along the second scan path 84b while energizing and deenergizing the blocking device 67. Further, rather than starting at the top of the scan pattern and moving downwardly, the image 80 could be formed by starting at the bottom of the scan pattern and moving the director 64 to direct the radiation beam 74 upwardly. Additionally, rather than moving the director 64 across the entire field of the fluorescent material 11, the director 64 could be used to "paint" an image, i.e., the director 64 could be moved or directed by the controller 68 to only trace over or within the actual area of the pattern or image to be formed. For example, to form the letter "P", the director 64 would point, e.g., direct the beam 74, only to the area within the confines of the letter "P" rather than sweeping the director 64 over the area outside of the area forming the fluorescent letter "P" which is to remain non-fluorescent. As will be appreciated by one of ordinary skill in the art, the invention is not limited to the type of rastering or scanning process used to form the image 80. For example, rather than the horizontal scanning methods described above, the scan pattern can be formed by using vertical scan paths with lateral

displacement at the end of the vertical scan path. Diagonal scan paths could even be used, if desired.

[0043] Alternatively, in an embodiment without the blocking device 67, the radiation source 60 could be energized and deenergized during formation of the scan pattern on the fluorescent material 11 to form a desired image.

[0044] As discussed above, for a vehicle head-up display the controller 68 can be in electronic communication with various on-board vehicle systems 72 to utilize the projection assembly 14 to form desired fluorescent images on the support 12. Examples of such images can include vehicle speed, vehicle system indicator lights (such as oil, generator, tachometer, etc.), navigational information from a GPS system, and a vehicle security system. For example, the controller 68 can be designed such that should the vehicle security system be activated, the radiation source 60, blocking device 67, and director 64 are controlled to fluoresce at least a portion of the fluorescent material 11 on the support 12 and/or to form particular phrases which would be readable by those outside the vehicle, such as "help" or "please notify police", etc. As a further example, the controller 68 can be in electronic communication, e.g., by radio wave, with a hand-held or pocket device, such as a key chain having a small radio wave transmitter, so that when the pocket device is activated, the horn sounds and/or the controller 68 activates the radiation source 60, blocking device 67 and directing system 62 to cause at least a portion of the fluorescent material 11 to fluoresce. This would be particularly useful in locating the vehicle in a crowded parking lot if the driver could not remember exactly where he parked the vehicle. In an additional example, images from video cameras operating in any wavelength range, such as visible or infrared, could be projected onto the support 12 carrying the fluorescent material 11 to form an image. In this manner, infrared cameras mounted on the vehicle could aid vision at night or under adverse weather conditions.

Cameras, e.g., mounted on vehicles, could also supplement vision available in the conventional fashion through windows and in mirrors.

[0045] As will be appreciated by one of ordinary skill in the art, more than one light emitting material, e.g., fluorescent material 11, can be carried on the support 12. The different fluorescent materials can be selected to fluoresce at different wavelengths or at different ranges of wavelengths and, hence, to fluoresce at different visible colors. A plurality of projection assemblies having different radiation sources 60 (the radiation sources 60 having respective output wavelengths within the absorption bands of the respective fluorescent materials) with respective directing systems 62 could be positioned in the vehicle so that different types of data can be displayed with different fluoresced colors. In Fig. 1, an optional second projection assembly 14′ is shown in dotted lines. For example, a first radiation source and fluorescent material combination can be utilized to display a first type of information, such as vehicle speed, by forming images of a first color, e.g., blue fluorescent images, on the support. This means that at least a portion of the fluorescent material on the support absorbs electromagnetic radiation in the wavelength or wavelength range emitted by the first radiation source and fluoresces at a selected visible wavelength or range in the blue region of the visible electromagnetic spectrum. Another source of information, such as vehicle status indicators, can be displayed using a second projection assembly having a second radiation source that is configured to fluoresce a second fluorescent material present on the support at a selected wavelength or range in a second color region, e.g., the yellow region, of the visible electromagnetic spectrum. If different fluorescent materials are deposited on the support, it would also be possible utilizing different laser devices to form colored images by simultaneously irradiating the fluorescent

materials such that the fluoresced light from the different fluorescent materials combine to form a selected color. In the example described immediately above, the two fluorescent materials can be simultaneously irradiated such that the resultant blue and yellow fluoresced images combine to form a green colored image.

[0046] Alternatively, a single fluorescent material 11 that fluoresces over a range of wavelengths dependent upon the wavelength(s) of the absorbed radiation can be provided on the support 12. For example, the fluorescent material 11 can fluoresce at one or more first fluorescent wavelength(s) (e.g., in the blue region of the electromagnetic spectrum) when irradiated by electromagnetic energy of one or more first irradiation wavelength(s) and fluoresce at a second fluorescent wavelength(s) (e.g., in the yellow region of the electromagnetic spectrum) when irradiated by electromagnetic energy of one or more second irradiation wavelength(s). In a still further embodiment, the plurality of radiation sources 60 described above can be substituted with a single radiation source capable of selectively emitting electromagnetic energy of two or more desired wavelengths or ranges or wavelengths such that the single radiation source is capable of providing electromagnetic energy in the absorption band(s) of the one or more fluorescent materials 11 to form separate images of differing color and/or an image of a desired (combined) color as described above.

[0047] An alternative projection assembly 110 of the invention is shown in Fig. 4. This projection assembly 110 is similar to the projection assembly 14 shown in Fig. 1 but the radiation source 60 is directly and movably connected to the movement device 66 so that the radiation source 60 can be moved and simultaneously energized and deenergized to form fluorescent images on the support 12 in similar manner as described above.

[0048] For use in a conventional automobile, the projection assemblies described above can be located in or under the vehicle dashboard, with the dashboard having a slot or opening of sufficient size to permit the beam 74 to pass through. However, the invention is not limited to placement of the projection assembly at this location. For example, if the display system 10 of the invention were incorporated into a side window, rear window, moon roof, etc., the projection assembly could be placed at any desired location in the vehicle to allow operation of the display device 10 as described above. Also, the controller 68 can be configured to vary the application of the energy from the radiation source 60 to modify the resultant fluorescent image to adjust for variations in curvature of the support 12.

[0049] While the above discussion was directed primarily to utilization of the invention in a vehicle head-up display, the invention is not limited to this use. The invention could be practiced in a brood range of information display or entertainment applications. For example, a support 12 as described above (whether a laminated support as shown in Fig. 1 or a monolithic support as shown in Fig. 2) could be used in a commercial location, such as a department store, grocery store, retail shop, etc., to display information regarding pricing information, upcoming sales, current specials, and the like. Unlike prior systems, the present invention would permit quick and easy changes and modifications to the displayed information utilizing the controller (e.g., a personal computer).

[0050] One exemplary use of the invention in the entertainment field would be in image displays for entertainment events, such as sporting events (e.g., football, baseball, hockey, basketball, and the like) or social events (nightclubs, bars, displays for shopping malls, and the like). For example, the invention could be used with a sound system

at a nightclub to display images related to particular songs being played.

[0051] The general concept of the invention will be described further with reference to the following Examples. However, it is to be understood that the following Examples are merely illustrative of the general concepts of the invention and are not intended to be limiting.

EXAMPLE 1

[0052] This example demonstrates forming fluorescent images utilizing a laser and a laminated support having fluorescent material located between the plies of the laminate.

[0053] A laminated article was formed using a 10 cm by 10 cm square piece of clear float glass 2 mm thick as a first ply and a 10 mm by 10 mm by 2 mm thick piece of SOLEX® glass commercially available from PPG Industries, Inc. of Pittsburgh, Pennsylvania as a second ply. SOLEX® glass has a green tint. To incorporate fluorescent material into the laminated article, 0.025 g of Uvitex OB fluorescent material commercially available from Ciba Specialty Chemicals Corporation was dissolved in 50 ml of methanol. This solution was then applied onto a glass blank by dipping a surface of the blank into the solution. The solution remaining on the glass blank was then allowed to dry for five minutes under a heat lamp to form a dried layer of fluorescent material on the blank. A major surface of the 10 cm by 10 cm clear glass ply described above was then pressed against the dried fluorescent material on the glass blank to adhere at least some of the dried fluorescent material onto the major surface of the clear glass ply. The SOLEX® glass ply and the clear glass ply with the adhered fluorescent material were then laminated together utilizing Grade B 180 SL polyvinyl butyral commercially available from E.I. duPont de Nemours Corporation to form an interlayer having a thickness of 0.5 mm. The clear glass ply was positioned such that the fluorescent material was on the

interior surface of the clear glass ply, i.e., on the side of the clear glass ply facing the interlayer. The lamination process included a vacuum stage and an autoclave stage. During the vacuum stage, the assembled parts of the article were subjected to a vacuum from a mechanical pump for seven minutes at room temperature and then for eighteen minutes at 255°F (124°C). During the autoclave stage, an automatic process controlled the pressure and temperature. The pressure was raised from atmospheric to 50 psi gage (3.5 kg/sq. cm) in ten minutes, held a 50 psi gage (3.5 kg/sq. cm) for ten minutes, raised to 200 psi gage (14 kg/sq. cm) in five minutes, held at 200 psi gage (14 kg/sq. cm) for thirty minutes, and decreased to atmospheric pressure in five minutes. The temperature was raised to 285°F (140°C) in ten minutes, held at 285°F (140°C) for thirty-five minutes, and allowed to cool for fifteen minutes. The laminated article was positioned on a support and an energy beam from a laser commercially available from Spectra-Physics and having a rated output of 7.5 mW at 350 nm was directed to the clear glass ply side of the laminated article. The absorption band for the fluorescent material, which has its peak at 375 nm, overlapped the wavelength of the laser output. The electromagnetic radiation from the laser caused the fluorescent material to fluoresce and produce a strong, visible blue dot where the laser beam was directed onto the clear glass ply side of the laminated article. The laser beam, reflected by a hand-held mirror, was moved across the clear glass ply side to cause the fluorescent material in the path of the laser beam to fluoresce. The laser beam was then directed to the SOLEX® glass ply side of the article and no fluorescence was detected. This indicates that the electromagnetic beam from the laser was not transmitted through the SOLEX® glass ply and/or polyvinyl butyral interlayer. Thus, the laser beam passes through the clear glass ply side, but not through the polyvinyl butyral and SOLEX® glass ply side of the article.

EXAMPLE 2

[0054] The laminated article from Example 1 above was used with a different projection system than described above.

[0055] The projection system used in this Example utilized a model LD1349 laser diode commercially available from Power Technology, Inc. and had a rated output of 5 mW at 395 nm to 397 nm. This wavelength range is also within the absorption band of the Ciba Specialty Chemicals Corporation fluorescent material incorporated into the laminated article. Again, the laser beam was directed to the clear glass ply side of the article and fluorescence was observed yielding a fluorescent blue light along the path of the laser beam.

[0056] Fig. 5 is a graph of percent transmittance vs. wavelength for a 2.1 mm thick piece of clear float glass (curve 112) and also for the laminated article (curve 114) described above in Example 1. As shown in Fig. 5, for these particular materials there is a "transmittance gap" 116 between the two curves. For example, energy at a wavelength of 370 nm has a transmittance of 70% through the clear glass but has a transmittance of 0% through the laminated article itself. Thus, if a fluorescent material having an absorption band which includes 370 nm is used in the laminated article, an energy beam of 370 nm can be directed through the clear glass side of the laminated article to cause fluorescence but will not pass through the rest of the laminated article.

[0057] While some exemplary embodiments and uses of the present invention have been described above, it will be readily appreciated by those skilled in the art that modifications can be made to the invention without departing from the concepts disclosed in the foregoing description. For example, although the invention was described above with particular use as a head-up display for a vehicle, the display system of the invention could be used in non-vehicular applications, such as the formation of images or information

displays on non-transparent surfaces in vehicles or elsewhere, such as walls, ceilings, or opaque screens. This information could include displays of advertisements, entertainment (such as light displays), or decorative patterns which could be changed as desired by an operator. Moreover, although the embodiments described above primarily utilized one or more fluorescent materials, it is to be understood that other types of light emitting materials, such as but not limited to phosphorescent material(s) could be used in lieu of or in addition to the fluorescent material(s). Accordingly, the particular embodiments described in detail herein are illustrative only and are not limiting to the scope of the invention, which is to be given the full breadth of the appended claims and any and all equivalents thereof.